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Photovoltaic Energy Systems Implemented in Public Buildings Located in the City of São Paulo

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ABSTRACT
With the increase of energy consumption and the environmental changes caused by energy generation, it is essential that different sectors of society seek alternative, sustainable and efficient ways to develop their activities. In this context, renewable energies generate less environmental pollution when compared to fossil sources. Among the renewable energy alternatives, solar energy has grown all over the world, thanks to new technologies, easy installation and energy collection, since it is powered by an abundant source with an inexhaustible impact on the earth's surface. Large buildings are considered potential polluters, as they can cause damage to the environment due to the amount of energy they use. The present study aims to analyze the photovoltaic solar system installed in a public building located in the city of São Paulo, specifically the project implemented in the Fazenda do Carmo Municipal Natural Park (PNMFC). A qualitative, single-case study, was the adopted methodology. Data collection was via the analysis of documents and semi-structured interviews with managers and those responsible for the PNMFC projects. The results showed that the generation of energy close to the place of consumption (distributed generation) is a determining factor for energy savings and minimization of environmental impacts. We conclude that public policies of fiscal and regulatory incentives are fundamental for the growth of the use of photovoltaic energy in urban centers.

KEYWORDS: Renewable energy. Photovoltaic solar energy. Public buildings.

1 INTRODUCTION

As world’s population increases, so does the demand for electric energy directed to the growth and development of urban and rural centers. With the increase of energy use, there is a greater consumption of natural resources and emission of greenhouse gases, such as CO_2, during the processes of energy generation (GOLDEMBERG; LUCON, 2007). In this scenario, developed and developing countries face difficulties to comply with the progressive energy demand and, at the same time, to find energy resources to supply economic growth (ALTOÉ; COSTA, *et. al*., 2017).

When it comes to energy production, two systems are mostly used worldwide. One is based on the energy from non-renewable sources, whose reserves are limited and need a long period, circa thousands of years, to be renewed. According to Nehring (2009), the main examples are fossil fuels, such as petroleum and coal, which have been the predominant source of energy for decades, supplying 85 to 93% of the energy produced in the globe. However, due to the increasing energy consumption and environmental changes caused by energy generation processes, it becomes essential that the many society sectors search for alternative, sustainable, and efficient means to carry out their activities without impacting the performance of previous ones.

In this context, renewable sources can generate enough energy to maintain the world’s growth, causing less hazardous environmental impacts, once their renovation cycle is natural. They also lead to a drastic reduction of environment pollution, when compared to the fossil fuel burning rates (BIZZARRI; MORINI, 2004; BIZZARRI; MORINI, 2006).

Among the renewable energy sources, the following can be cited: wind energy, derived from the kinetic energy of air masses that circulate thanks to the uneven heating of the Earth's surface; biomass energy, derived from the chemical energy produced by plants via photosynthesis in the form of carbohydrates; hydroelectric energy, derived from the kinetic energy of river waters while flowing from high altitudes towards the sea; and solar energy, which is the focus of this study (PACHECO, 2006).

From the point of view of renewable energy sources used in great cities, sustainability of existing buildings is an issue that stands out, once large quantities of energy are spent in ventilation, illumination, heating, and cooling. The concept Zero Energy Buildings (ZEB) was defined by Espinosa; Hernández and Espinoza (2018), who postulated that the total annual quantity of energy used by a building equals the quantity of renewable energy created *in loco*, thus promoting the mitigation of CO_2 emissions and making buildings energy self-sufficient.

As mentioned by the *Ministério de Minas e Energia* (Ministry of Mines and Energy – MME, 2015), until 2015 the consumption of electric energy in Brazilian buildings corresponded to approximately 50% of the total electricity consumed in the country. Therefore, buildings, besides great water consumers and producers of large volumes of waste, are responsible for circa a third of all CO_2 emissions in great cities (MEMON, 2014).

Deficient buildings, equipped with low-efficiency electrical appliances, combined with inefficient energy savings practices, are a significant factor that contributes to high electricity consumption (OPOKU, ADJEI, *et al*., 2020). As a consequence, costs due to the high electricity consumption in public institutions are a great challenge for many nations worldwide, specially developing countries (GYAMFI; DIAWUO, *et al.* 2018).

Therefore, interventions and energy efficiency policies focusing on less consumption and lower costs should be encouraged in buildings (EL-DARWISH; GOMAA, 2017). The public sector can benefit from the implementation of photovoltaic solar energy, envisaging a better exploitation of its economic potential and allocation of resources for other purposes (Müller, 2014). When using photovoltaic technologies and energy management devices, a significant reduction of energy consumption in buildings can be achieved (ALHAGLA; MANSOUR, *et al*, 2019).

We opted to study a public building located in the city of São Paulo, capital of the State of São Paulo (southeastern Brazil). The State of São Paulo, with more than 45 million inhabitants, is the greatest industrial park of Latin America. It responded for 27% of the energy consumed in Brazil in 2017 (PURIFICAÇÃO; RAMOS, *et al.,* 2020).

Having in mind the growing importance of the use of renewable energy sources in buildings, the objective of this study was to assess the contribution of the implementation of a PV system in the Fazenda do Carmo Municipal Natural Park (PNMFC), located in São Paulo city. The following question was formulated to guide our study: How did the implementation of the PV solar energy project contribute to the improvement of the Fazenda do Carmo Municipal Natural Park?

Considering the criteria presented in the methodology, the Fazenda do Carmo Municipal Natural Park (PNMFC) was chosen for its major environmental relevance, thanks to its native vegetation as springs. Located in the eastern zone of the city of São Paulo, PNMFC developed the first sustainable public building in the city, with a project that pursued self-generated energy by means of the installation of PV solar panels, and hence minimize local environmental impacts (SECRETARIA DO VERDE E MEIO AMBIENTE, 2014).

2. THEORETICAL REFERENCE

Among the renewable energy sources, solar energy stands out for its high energy potential and abundance. The range of solar radiation that reaches the Earth's surface varies from 0.06 kW/m^2 in high latitudes to 0.25 kW/m^2 in low latitudes (GÓMEZ; CARLESSO, *et al.*, 2018).

Used since the beginning of humanity to make fire and heat dwellings, water, and food, solar energy has lost importance for a certain period in the 20^{th} century due to the increasing use of fossil fuels (BELESSIOTIS; PAPANICOLAOU, 2012). From the 1970's on, with the rising prices of fossil fuels and the energy crises after the wars, the interest in solar energy as an alternative has risen again, with estimates that this source will represent more than 25% of the global electric matrix in 2040 (ANEEL, 2008).

With a greater diversification of the electric matrix and pursuing the supply of clean energy, the use of solar energy has exponentially grown since the beginning of the decade. Solar radiation generates electric current by means of the photovoltaic (PV) effect, which directly converts solar light into electric current. By means of controllers and converters that collect and process sunlight, the electric current can be directly used or stored in batteries (VILLALVA, 2012; SANTOS; JABBOUR, 2013).

Solar cells are PV devices able to transform energy coming from a light source into electricity. They are usually disposed in assemblies called solar modules, equipped with technologies that allow them to withstand antagonistic environmental conditions (SANTOS, 2011). The PV panel is composed of a solar module, charge controller, batteries, and inverter, and is the unit of a PV solar system (CARVALHO; RIFFEL *et al*, 2004 and SANTOS; JABBOUR, 2013).

The PV solar system can be classified in two ways: off-grid or stand-alone PV systems (Figure 1), which supply energy to areas that are not easily accessible or have no access to an electric grid, being the energy stored in batteries for further use; and on-grid PV systems (Figure 2), which are connected to an electric grid and operate concomitantly with it (VILLALVA, 2012).

Figure 1: Off-grid PV system

Figure 2: On-grid PV system

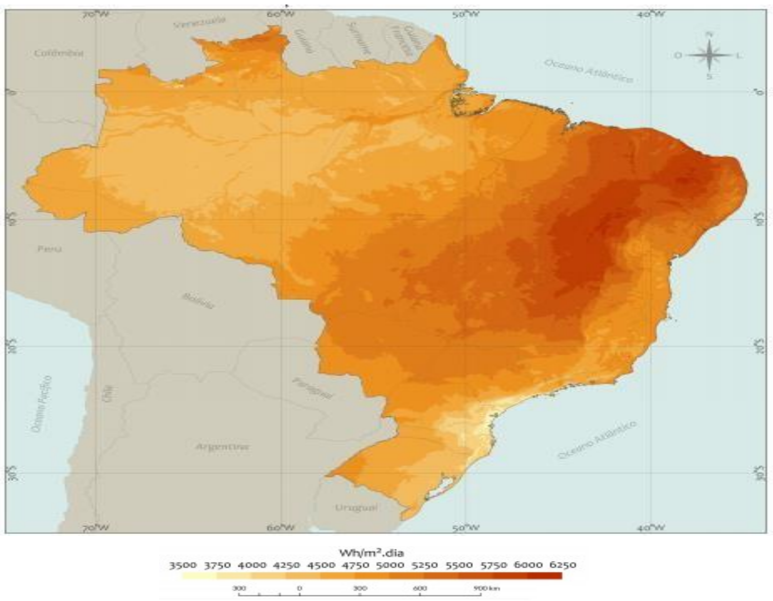
Source: Recovered from "*Desenvolvimento de conversores estáticos para sistemas FV autônomos*" (Development of static converters for autonomous PV systems – Imhoff, 2007).

The speed at which PV systems have developed in recent years is a consequence of their capacity to cover most market segments, ease of installation, and costs reduction. With such advantages, PV energy has the potential to become the most important source of electricity in the long run, thanks to the abundance of solar energy, distribution, and on-going investments in technologies (FERREIRA, KUNH *et al.*, 2018). It is surprising that, despite the great potential of solar energy in Brazil, incentives to the development of PV technologies in the country are still incipient (SILVA, 2018).

The European Union (EU) encourages the development of the energy market with a series of legal instruments that regulate the rational use of energy and of renewable energy sources, such as solar energy, even if the geographic positioning of some EU countries is unfavorable for the use of solar energy throughout the seasons of the year (FERNÁNDEZ, 2011). An example is Germany: despite its unfavorable geographic positioning in respect to solar radiation, it follows a robust program of diversification and simultaneous "cleaning" of the local electric matrix. With investments in the use of renewable energy sources for the generation of electricity, Germany represents almost 50% of the installed solar potential in relation to the world's total (ANEEL, 2008).

Even if solar radiation is favorable to PV energy production in Brazil, it still represents less than 0.1% of the national electric matrix (BONDARIK; PILATTI *et al.,* 2018). Figure 3 shows the total annual horizontal radiation to which the Brazilian territory is exposed. Maximum radiation occurs in the northeastern region of the country, the State of Bahia presenting the highest index – 6.5 kWh/m^2.day, followed by the states of Piauí, Paraíba, Rio Grande do Norte, and Ceará. The states of Tocantins and Goiás show the highest indices of central Brazil, and the states of Minas Gerais and São Paulo of the southeastern region. The smallest index corresponds to the State of Santa Catarina, in the southern region, with 4.25 kWh/m^2.day. It exceeds that of Germany, EU country with the highest investments in PV solar energy and maximum solar radiation of 3.44 kWh/m^2.day (PEREIRA *et al*., 2017).

Figure 3: Map of the solar radiation in Brazil (in Wh/m^2.day)



Source. Recovered from "*Atlas Brasileiro de Energy Solar*" (Brazilian Atlas of Solar Energy – Pereira et al, 2017, p. 36).

As mentioned in the World Wildlife Fund summary (WWF-Brasil, 2012), it is necessary that policies that promote large-scale PV energy generation be established, so that Brazil can grow and therefore dominate the PV energy production chain.

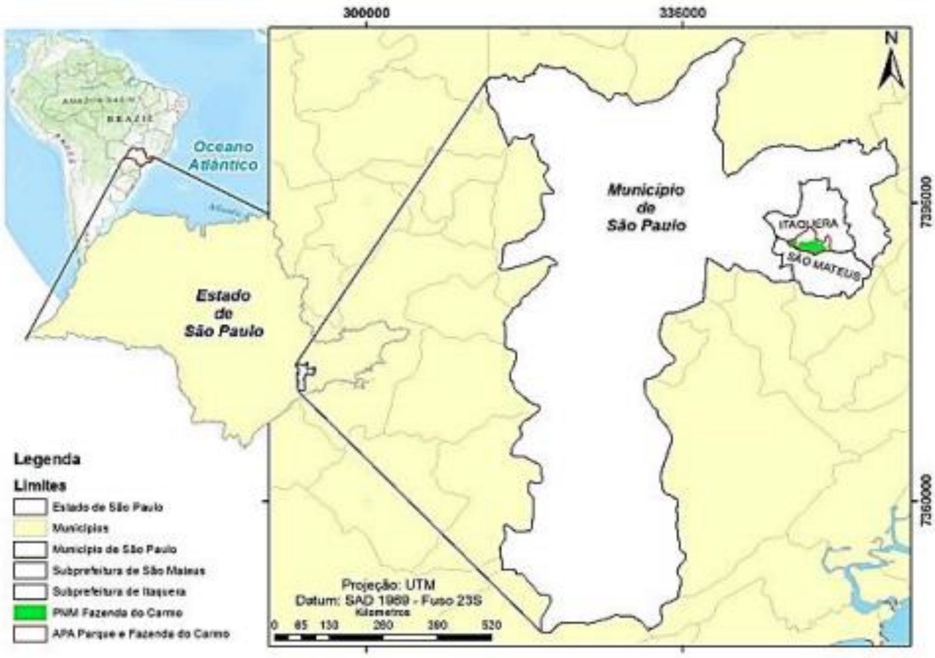
3 METHODOLOGY

In order to understand the main concepts and the theme itself, the character of this study is exploratory. It is a case study in which, as determined by Creswell (2007), the researcher explores a fact, activity, process or individual(s) in depth, grouping the data by time and activity. We opted for a single case study, which, according to Eisenhardt (1989) and Yin (2015), it refers to the unparalleled deepening of individual, organizational, social and political phenomena, useful when the objective of the study is to deepen the knowledge on several aspects of a single research object.

At first, a survey was carried out to identify buildings in the city of São Paulo that have already implemented PV solar panel systems and received the Leadership in Energy and Environmental Design (LEED) stamp. This certification was created in 2000 by the Green Building Council (USGBC) with the objective of guiding and analyzing the commitment of buildings with sustainable principles, from the project design to the daily use of the building's installations (GBCBrasil) (GOMES, 2018). Some criteria were defined to select the study case. The building should: be located in the city of São Paulo; belong to the Public Sector; have a PV solar panel system for the supply of electric energy, and a PV system project implemented for more than two years. Considering these criteria, the *Parque Natural Municipal Fazenda do Carmo* (Fazenda do Carmo Municipal Natural Park) was chosen as object of study.

The Fazenda do Carmo Municipal Natural Park is located in the eastern zone of São Paulo municipality (Figure 4) and is the largest and most important ecological reserve of the Itaquera neighborhood. Decreed by Law 6409, dated 5th April 1989, and regulated by Decree 37678, dated 20th October 1993, the *Área de Proteção Ambiental Parque e Fazenda do Carmo* (Environmental Protection Area – *APA Parque e Fazenda do Carmo*) encompasses two different Conservation Units – The Fazenda do Carmo Municipal Natural Park (PNMFC), object of this study, and the *Unidade de Conservação de Proteção Integral Parque do Carmo-Olavo Egydio Setúbal* (Carmo-Olavo Egydio Setúbal Park Full Protection Conservation Unit – PCOES) (SECRETARIA DO VERDE E DO MEIO AMBIENTE, 2014).

Figure 4: Location of the Fazenda do Carmo Municipal Natural Park (PNMFC) in São Paulo municipality.



Source: SECRETARIA DO VERDE E MEIO AMBIENTE (SVMA), 2014.

The collection of data was carried out via the analysis of documents and semi-structured interviews. The documents were made available by the PNMFC managers and the electrical engineer responsible for the development of the building's project. The documents are listed in Table 1, together with the codes used to identify them in the analysis of the results.

Table 1 – Documents analyzed for this study

Document	Description	Code Used
Solar energy in SVMA: Concepts, present scenario, perspectives, challenges, and benefits	It presents the present scenario and perspective of the use of solar energy in SVMA.	D1
Project for the Fazenda do Carmo Municipal Natural Park, by Rogério Vaz S. Anachoreta	It presents all the steps followed during the development of the project for the installation of the PV solar system.	D2
Minimum requirements to interlink the distributed micro- and mini-generation to Eletropaulo distribution grid with permanent use of parallel connected inverters – high, medium and low voltage consumers.	It presents the necessary items for distributed generation to take place in a construction.	D3
Report on the access to the Eletropaulo distribution grid for micro- and mini-generation	It presents the necessary items for a construction to have access to the micro- and mini-generation distribution grid.	D4
Descriptive memorial of the PNMFC head office building.	It describes in detail all the items and steps followed during the construction of the PNMFC head office building.	D5

Source: prepared by the authors, 2021.

PNMFC managers, engineers, and architects responsible for constructing and administering the PNMFC head office building were interviewed. A semi-structured guide was prepared containing 29 questions, divided in six groups and covering the following items: planning, installation, monitoring, Normative Resolution, predictions and details on the project. After prior authorization via consent forms, interviews were made and recorded. The audios were transcribed and interpreted. Table 2 presents a list of the specialists interviewed for this study and the codes used to identify them in the analysis of the results.

Table 2: Specialists interviewed for this study

Position	Question blocks applied	Date of the interview	Code used
Director of the SVMA Division of Biodiversity Conservation Units and Municipal Herbarium	Blocks 1 and 7	8th March 2021	AM
PNMFC manager	Complete interview	18th February 2021	HS
Coordinator of SVMA projects and works	Blocks 1, 5, 6, and 7	18th February 2021	LL
Electrical Engineer	Blocks 2, 3, 4, 5, and 6	23rd February 2021	RA

Source: prepared by the authors, 2021.

The interviews with the main specialists responsible for the PV solar system planning and installation were fully satisfactory, making new interviews unnecessary, as no new elements would be found or incremental learning (obtained from the new interviews) would be minimal (EISENHARDT, 1989). The identification of the theoretical saturation becomes a determining criterion for interrupting data collection. As defended by Fraser and Gondim (2004), the important factor is not how many individuals are interviewed, but whether the interviewees were able to bring significant contents to the proposed theme.

4 RESULTS AND DISCUSSION

PNMFC represents the largest remnant of the *Mata Atlântica* (Atlantic Forest) in the eastern zone of São Paulo municipality, with an area of 867600 hectares (Figure 5). The park is

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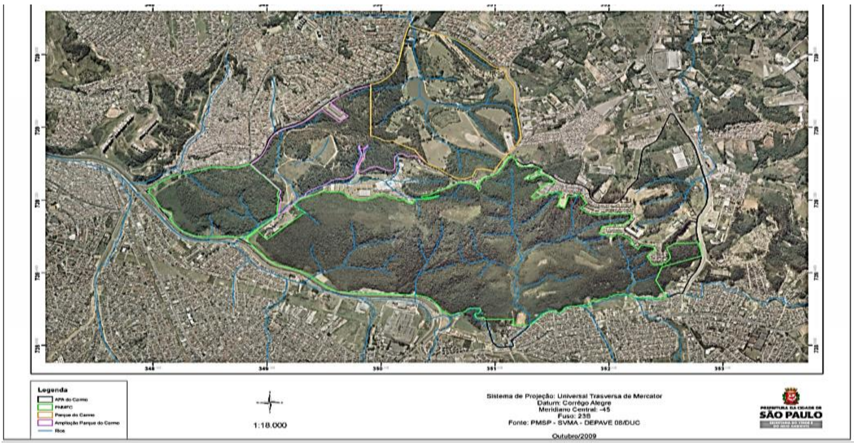
the first Full Protection Conservation Unit created in the urban area of São Paulo municipality (FERREIRA, 2014).

Figure 5: Limits of the *APA Parque e Fazenda do Carmo* (black line), *Parque do Carmo* (brown and purple lines), and PNMFC (green line). Drainage represented with blue lines.



Source: Recovered from the SECRETARIA DO VERDE E MEIO AMBIENTE (SVMA), 2021.

4.1 Details of the case study

As cities grow, the creation of *Áreas de Proteção Ambiental* (environmental protection areas – APA) are necessary, in order to protect forest remnants. As mentioned by interviewees AM and HS, PNMFC was created in 1989 with the name *Fazenda Nossa Senhora do Carmo*, at which time there was a large coffee plantation. At present there is an extensive area covered with remnants of the *Mata Atlântica* (Atlantic Forest) and divided between the APA *Parque e Fazenda do Carmo* (Carmo Park and Farm) and PNMFC.

We chose PNMFC as object of this study. The aim of PNMFC is the preservation and recovery of the local original ecosystem characteristics, as well as the promotion of scientific research and development of environmental education activities. Having these objectives in mind, the new PNMFC head office building (Figure 6) was inaugurated in January 2019 (SECRETARIA ESPECIAL DE COMUNICAÇÃO, 2019).

Figure 6: PNMFC head office building

Source: prepared by the authors, 2021.

As stated in D5 and mentioned by HS "the building was designed thinking on efficiency and low impact; as a result, it became the first sustainable building of the municipality". This description is complemented by LL:

> "The building has a rainwater harvesting system, which stores the collected rainwater for its own use. In addition, the building is in charge of the sewage treatment with macrophytes, which have the ability to remove toxic substances from the water, providing favorable conditions for the effluent. It also equipped with a photovoltaic solar system, which was the focus of this study; the surplus of the generated energy is returned to the electrical grid".

4.1.1 Architecture of the building

The project of the PNMFC head office building pursued environment-friendly alternatives, such as the reduction of waste production since its construction, as explained by interviewee LL: "the architecture project was developed in an economic way, in order to spend less energy with ready-made structures". The construction sector, besides being a great consumer of natural resources, is equally a great generator of waste, because a solid management program is inexistent (ORTEGA, 2014).

Wooden structures were chosen for the construction of the PNMFC head office building, because the environmental impact is substantially less than that of concrete or steel structures. As stated in D5, the production of a ton of wood consumes circa 325% less energy than the production of a ton of concrete.

Another characteristic of the construction that took into account the respect and preservation of the topography and the natural particularities of the terrain – item available in D5 and exposed by interviewees HS and LL – was the choice of a risen building, touching the ground with metallic structures, a model that is based on the characteristics of a stilt house, as shown in Figure 7.

Figure 7: Metallic structure to support the head office building

Source: Mata Atlântica Atlas, 2019.

4.1.2 Sewage treatment

The sewage produced in the PNMFC head office building is treated by a system known as wetland. According to Silveira, Wink *et al.* (2019), it is an alternative for the pre-treatment of urban effluents using natural mechanisms, such as macrophytes, vegetation with a great potential for energy and nutrient recovery at low costs, in addition to promoting the reduction of environmental pressure indices in wastewater recovery processes. According to Esteban and De Miguel (2008), the wetland system can be seen as the best and most widespread treatment for water reuse in irrigation.

4.1.3 Rainwater harvesting

A rainwater harvesting system is also installed in the PNMFC head office building. As described by interviewee HS: "rainwater is collected by gutters and directed to two tanks located at the back of the building, so that it can be used for irrigation and other similar purposes". In Brazil, policies regarding collection and use of rainwater are still scattered and make it difficult to visualize the country's position regarding the regulation of the sector (PACHECO; GÓMEZ *et al.*, 2017).

As detailed by HS:

> "The PNMFC head office building was initially planned for rainwater collection and distribution at the point of use".

4.1.4 Energy performance

The PNMFC head office project also sought an adequate orientation of the building, with the due evaluation and construction aiming at a better energy performance, besides providing ambient comfort inside the building. As mentioned by interviewee HS:

> "The distribution of internal spaces was planned with criteria that guarantee a correct transversal ventilation of all spaces, as well as a better use of natural light by means of skylights installed on the roof, and doors that allow wide openings".

Interviewee RA – the engineer responsible for the project – reported the motivation for the installation of a PV solar system in PNMFC:

> "The Municipal Prefecture of São Paulo (PMSP) is the owner of the largest area of the city of São Paulo. Energy generation, when well planned and performed, is an opportunity to use an abundant resource. With the good use of available and created open areas, the cost of the electric energy can be zeroed within the SVMA and later in the whole PMSP".

According to interviewee RA and reported in D3 and D4, during planning, the following steps were followed:

- Choice of the site: Check the best site for the installation of the solar tree;
- Measurements of the solar potential and infrastructure adaptation: Check whether the chosen site presents the best solar potential;
- Approval of the site: Firstly mentioned by the manager;
- Choice of supplier;
- Preparation of the Gantt Diagram;
- Document procedures;
- Authorizations of heritage agencies;
- Start of the assembly and all initial tests;
- End of the assembly and final tests;
- Quantification of savings: Start two years after the installation.

Interviewee HS stated that, for all steps to be reached, ten years of research and meetings were necessary, to finally start the installation of PV solar panels in PNMFC in 2018. After the planning of the head office building, the installation started in 2018 and ended in 2019. As mentioned by all interviewees (AM, HS, LL, and RA), no obstacles were found. Differently from Purificação; Ramos *et al.* (2020), who mentioned that high initial investment is perceived as the main obstacle regarding PV energy, as PNMFC is a public space and the installation became feasible via environmental compensation, no initial obstacles were found.

As the *Secretaria do Verde e Meio Ambiente* (Secretariat for the Green and Environment – SVMA) is a municipal public agency, it made use of the compensation system as a facilitator, involving the *Metrô de São Paulo*, the latter in process of obtaining the environmental license for the installation of the monorail (line 15 – silver). According to Purificação; Ramos *et al*. (2020), compensation is a type of policy that encourages distributed generation (a variety of technologies that generate electricity at or near where it will be used), by which consumers who produce their own electricity are allowed to use it as credit.

As described in D2 and D5, the PV solar panel system developed in PNMFC has the innovative shape of a tree and a small footprint (space occupied in the terrain). As the PV solar panels face north, solar radiation absorption is improved. This is an excellent format to be replicated in different areas, as explained by interviewees HS and RA.

When detailing the installed system, interviewee RA mentions that:

> “The system chosen to be installed is of small size, but generated power enough to supply most part of the day and the year the PNMFC daily energy demand”.

According to D1, D2, D4, and D5, the tree, composed of twenty-two 150-W panels, is installed in an area of 22 m^2 (Figure 8), with a capacity to reach an electric power of 3 kW and generate 500 to 700 kWh/month (Table 3).

Figure 8 – Lower part of the infrastructure of photovoltaic solar system

Source: prepared by the authors, 2021.

Table 3 - Photovoltaic solar system data

System	Units	Nominal Power (kW)	Effective Power (kW)	First Synchronization for Testing	Start of the Operation
Tree-shaped	22	3.30	3	2018	2019

Source: Adapted from Eletropaulo, 2018.

According to D4, the central generator is composed of a 3-kW inverter, in which the produced energy is exported by the Enel (former Eletropaulo) electric system, totaling a maximum of 3 kW, which corresponds to the net power of the electric energy to be produced by the tree.

One of the positive aspects of the PV solar system, according to HS and RA, is that it is not necessary that PNMFC allocate a team specifically trained to deal with the equipment, once it does not require detailed cleaning before five years of installation.

According to interviewee LL:

> "*A priori*, as the maintenance of the system should be performed by PNMFC, it would be necessary that a maintenance team be in charge of it, as for periodic cleaning. But training of PNMFC personnel is not necessary, because the maintenance does not require technical qualification or training of some sort".

When asked about the useful life of the solar system implemented in PNMFC, the electrical engineer responsible for the installation (interviewee RA) answered:

> "The secret of an installation for any purpose is that it is long lasting. Nowadays there are solar panels that start losing efficiency after five years and others after 15 years. Thus, it is estimated that the panels installed in the park have a 15-year periodicity; following the efficiency decaying, there will be no more generation after 20 years".

According to interviewee HS:

> "All the system was implemented in the PNMFC head office building as a big model so that people could think about it a bit, once the renewable energy issue calls attention for promoting savings, and what difference it makes when a public manager (prefect/governor) starts to think about and approve projects as that of the park".

Interviewee AM stated that:

> "The PNMFC project is a milestone, showing that it is necessary to dare, it is necessary to subvert things so that new levels are reached with better sustainability results inside public buildings. As it is at first necessary to break the bonds of public power in relation to agility, in this sense the construction of the PNMFC head office building was a barrier break and it is hoped that this project can be spread to other spaces, respecting their individualities".

The main information, when opting for an alternative energy system, is how long it will take for the return of the amount invested in the PV installation. According to RA and LL, the payback estimated in 2020 would be due in 4-5 years, as a function of the increased regulatory support and development of technologies. According to Yu, Popiolek *et al.* (2014), the government subsidy policies provide direct and indirect results in the short and long term in the technological, economic and energy aspects of the society.

As determined by the company and available in D2, after five years, a complete checkup of the PV system is necessary, in order to check all pieces of equipment. Should adverse factors occur before this deadline, as falling branches or hailstorms, a technical team is called

(RA and HS). Therefore, for the installation to reach a useful time of 15 years, a maintenance every six months is performed by the engineering team, in order to check whether the equipment presents defects in the panels or software (RA and HS).

5 CONCLUSION

Renewable energy offers the possibility of diversifying energy sources, allowing to minimize the release of greenhouse gases, which usually occurs when fossil fuels are used, and therefore minimize environmental impacts. The results obtained in this study helped understand that the implementation of PV solar systems, in order to promote distributed generation, aids public buildings destined to different fronts and located in different regions to perform their base functions and at the same time minimize the use of electric matrix, relieving the distribution system, reducing costs, and minimizing environmental impact.

Regarding the PNMFC head office building, the first sustainable building of São Paulo municipality, this study tried to present the steps established for the installation of the PV distributed energy, considering as methodology the analysis of documents and semi-structured interviews with the specialists responsible for the implementation and management of the PNMFC head office building project. Thanks to the excellent planning that lasted for 10 years, the implementation of a PV solar system was feasible – at the moment, it supplies energy for the building with the expectation of a 100% return, besides representing savings to public coffers. Planning also made possible that the implemented items helped validate the building as sustainable, certifying it as a milestone of the Municipal Prefecture of São Paulo, a model to be followed in other areas of the city and even of the country.

However, in order to make new projects similar to that of the PNMFC head office building feasible, it is necessary that the bonds that tie public power to pre-defined models be broken, so as to diversify and comply with the particular building characteristics, with the implementation of the energy system that is best adaptable to the construction, thus promoting savings and the energy efficiency. It is recognized that it is mandatory to increase government incentives by means of public policies, either via subsidies or financing, once they play a fundamental role in promoting the distributed generation of PV energy.

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6 REFERENCES

ALHAGLA, K.; MANSOUR, A.; ELBASSUONI, R. Optimizing windows for enhancing daylighting performance and energy saving. **Alexandria Engineering Journal**, v. 58, n. 1, p. 283-290, 2019.

ALTOÉ, L. et al. Políticas públicas de incentivo à eficiência energética. **Estudos Avançados**, v. 31, p. 285-297, 2017.

AGÊNCIA NACIONAL DE ENERGIA ELÉTRICA. Atlas de energia elétrica do Brasil. 3ed. Brasília, DF, 2008. Recovered from http://www2.aneel.gov.br/arquivos/PDF/atlas3ed.pdf.

BELESSIOTIS, V. G.; PAPANICOLAOU, E. History of Solar Energy. 2012.

BIZZARRI, G.; MORINI, G. L. Greenhouse gas reduction and primary energy savings via adoption of a fuel cell hybrid plant in a hospital. Applied Thermal Engineering, v. 24, n. 2-3, p. 383-400, 2004.

BIZZARRI, G.; MORINI, G.L. New technologies for an effective energy retrofit of hospitals. **Applied Thermal Engineering**, v. 26, n. 2-3, p. 161-169, 2006.

BONDARIK, R.; PILATTI, L. A.; HORST, D. J. Uma visão geral sobre o potencial de geração de energias renováveis no Brasil. **Interciencia**, v. 43, n. 10, p. 680-688, 2018.

CARVALHO, P. C. M. et al. The Brazilian experience with a photovoltaic powered reverse osmosis plant. **Progress in Photovoltaics: Research and Applications**, v. 12, n. 5, p. 373-385, 2004.

CRESWELL, J. W. Projeto de Pesquisa: Métodos Qualitativo, Quantitativo e Misto (2ª.ed.) Porto Alegre: Artmed, 2007.

EISENHARDT, K. M. Building theories from case study research. **Academy of management review**, v. 14, n. 4, p. 532-550, 1989.

EL-DARWISH, I.; GOMAA, M. Retrofitting strategy for building envelopes to achieve energy efficiency. **Alexandria Engineering Journal**, v. 56, n. 4, p. 579-589, 2017.

ELETROPAULO. Parecer de Acesso à Rede de Distribuição da Eletropaulo para Micro e Minigeração, 2018.

ESPINOSA, V. M.; HERNÁNDEZ, J. R. H.; ESPINOZA, J. C, T. Gestión de la eficiencia energética en las edificaciones del Ecuador. **Opuntia Brava**, v. 10, n. 4, p. 309-314, 2018.

ESTEBAN, R. I.; DE MIGUEL, E. O. Present and future of wastewater reuse in Spain. **Desalination**, v. 218, n. 1-3, p. 105-119, 2008.

FERNÁNDEZ, P. S. El reto europeo: la eficiencia energetica en edificios. La nueva directiva comunitaria 2010/31. **Seqüência: estudos jurídicos e políticos**, v. 32, n. 62, p. 55-77, 2011.

FERREIRA, A. et al. Economic overview of the use and production of photovoltaic solar energy in brazil. **Renewable and Sustainable Energy Reviews**, v. 81, p. 181-191, 2018.

FERREIRA, R. Estrutura Da Guilda Das Aves Frugívoras Da APA Parque e Fazenda Do Carmo, São Paulo, Brasil. **Enciclopédia Biosfera**, v. 10, n. 18, 2014.

FRASER, M. T. D.; GONDIM, S. M. G. Da fala do outro ao texto negociado: discussões sobre a entrevista na pesquisa qualitativa. **Paidéia (Ribeirão Preto)**, v. 14, p. 139-152, 2004.

GOLDEMBERG, J.; LUCON, O. Energia e meio ambiente no Brasil. **Estudos avançados**, v. 21, n. 59, p. 7-20, 2007.

GÓMEZ, J. M. et al. A irradiância solar: conceitos básicos. **Revista Brasileira de Ensino de Física**, v. 40, 2018.

GYAMFI, S. et al. The energy efficiency situation in Ghana. **Renewable and Sustainable Energy Reviews**, v. 82, p. 1415-1423, 2018.

IMHOFF, J. et al. Desenvolvimento de conversores estáticos para sistemas fotovoltaicos autônomos. 2007.

MEMON, S. A. Phase change materials integrated in building walls: A state of the art review. **Renewable and sustainable energy reviews**, v. 31, p. 870-906, 2014

NEHRING, R. Traversing the mountaintop: world fossil fuel production to 2050. Philosophical Transactions of the Royal Society B: Biological Sciences, v. 364, n. 1532, p. 3067-3079, 2009.

OPOKU, R. et al. Energy efficiency, solar energy and cost saving opportunities in public tertiary institutions in developing countries: the case of KNUST, Ghana. Alexandria Engineering Journal, v. 59, n. 1, p. 417-428, 2020.

ORTEGA, S. G. Sustentabilidade na Construção Civil: significados, práticas e ideologia. **Organizações e Sustentabilidade**, v. 2, n. 1, p. 112-137, 2014.

PACHECO, F. Energias Renováveis: breves conceitos. **Conjuntura e Planejamento**, v. 149, p. 4-11, 2006.

PACHECO, P. R. C. et al. A view of the legislative scenario for rainwater harvesting in Brazil. **Journal of cleaner production**, v. 141, p. 290-294, 2017.

PEREIRA, E. B. et al. Atlas brasileiro de energia solar. **São josé dos campos: Inpe**, v. 1, 2017.

PURIFICAÇÃO, R. A. N.; RAMOS, H. R. R.; KNIESS, C. T. Barreiras e facilitadores para o uso da energia fotovoltaica: uma revisão sistemática da literatura. **Periódico Eletrônico Fórum Ambiental da Alta Paulista**, v. 16, n. 2, 2020.

SANTOS, J. B.; JABBOUR, C. J. C. Adoção da energia solar fotovoltaica em hospitais: revisando a literatura e algumas experiências internacionais. **Saúde e sociedade**, v. 22, p. 972-977, 2013.

SECRETARIA ESPECIAL DE COMUNICAÇÃO. Sede do Parque Natural Fazenda do Carmo é o primeiro prédio público municipal sustentável, 2019. Available on http://www.capital.sp.gov.br/noticia/sede-do-parque-natural-fazenda-do-carmo-e-o-primeiro-predio-publico-municipal-sustentavel

SECRETARIA DO VERDE E MEIO AMBIENTE DO ESTADO DE SÃO PAULO. Plano De Manejo Parque Natural Municipal Fazenda Do Carmo, 2014. Available on https://www.prefeitura.sp.gov.br/cidade/secretarias/meio_ambiente/publicacoes_svma/index.php?p=18104444

SECRETARIA DO VERDE E MEIO AMBIENTE DO ESTADO DE SÃO PAULO. Parque Natural Municipal Fazenda Do Carmo,2021. Available on https://www.prefeitura.sp.gov.br/cidade/secretarias/meio_ambiente/unid_de_conservacao/index.php?p=42141

SILVA, A. O. Exploração de recursos renováveis em escolas públicas: caso Escola Estadual Ensino Fundamental Eduardo Vargas. 2018.

SILVEIRA, E. O. et al. Sistema integrado com microalgas e wetland construído de fluxo vertical no tratamento de efluentes urbanos. **Engenharia Sanitária e Ambiental**, v. 24, p. 305-313, 2019.

VILLALVA, M. G.; GAZOLI, J. R. Energia solar fotovoltaica: conceitos e aplicações. **São Paulo: Érica**, v. 2, 2012.

WORLD WILDLIFE FUND FOR NATURE BRASIL. Além de Grandes Hidrelétricas. Políticas para fontes renováveis de energia elétrica no Brasil. Sumário WWF Brazil. Brasília: Author, 2012. Recovered from https://d3nehc6yl9qzo4.cloudfront.net/downloads/alem_de_grandes_hidreletricas_sumario_para_tomadores_de_decisao.pdf

YIN, R. K. **Estudo de Caso-: Planejamento e métodos**. Bookman editora, 2015.

YU, H. J. J.; POPIOLEK, N; GEO.FFRON, P. Solar photovoltaic energy policy and globalization: a multiperspective approach with case studies of Germany, Japan, and China. **Progress in Photovoltaics: Research and Applications**, v. 24, n. 4, p. 458-476, 2016.